ENVIRONMENTAL STUDIES
IN THE VICINITY OF THE
SUSQUEHANNA STEAM ELECTRIC STATION

2010
WATER QUALITY
FISHES

Prepared by

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INTRODUCTION

PPL Susquehanna, LLC (PPL) contracted Ecology III, Inc. to conduct nonradiological monitoring of the Susquehanna River in the vicinity of the Susquehanna Steam Electric Station (Susquehanna SES) in 2010. The Susquehanna SES is a nuclear power station with two boiling water reactors, each with a net electrical generating capacity of approximately 1,350 megawatts. It is located on about 1,700 acres on the west side of the Susquehanna River in Salem Township, Luzerne County, 5 miles northeast of Berwick, Pennsylvania. In addition, approximately 700 acres of mostly undeveloped and recreational lands owned by PPL are located on the east side of the Susquehanna River in Conyngham and Hollenback Townships. PPL owns 90% of the station and Allegheny Electric Cooperative, Inc. owns 10%.

The objective of the nonradiological environmental monitoring program is to assess the impact of operating the Susquehanna SES on the Susquehanna River water quality and relative abundance of fishes. This was accomplished in 2010 by comparing data at control and indicator stations and by evaluating results of preoperational (1971-1982) and operational (1983-2009) studies (Ichthyological Associates 1972, Ichthyological Associates, Inc. 1973-1985, Ecology III, Inc. 1986-2010). Monitoring was done at sites within a control station (SSES) upriver from the Susquehanna SES river intake structure and indicator station (Bell Bend) downriver from the discharge diffuser.

To more objectively assess the impact of operating the Susquehanna SES on the Susquehanna River, a statistical procedure called BACI (Before-After:Control-Impact) analysis was applied to preoperational and operational fishes monitoring data.

This report presents results of water quality and fishes studies.

WATER QUALITY

PROCEDURES

Water quality of the Susquehanna River relative to operation of the Susquehanna SES was monitored throughout 2010 at four locations (Table 1, Fig. 1). Susquehanna River water samples were collected quarterly at SSES (control) and Bell Bend (indicator). In addition, water samples were also collected quarterly from the cooling tower blowdown of the Susquehanna SES. River flow and temperature were monitored continuously at the Environmental Laboratory (Table 2).

Most of the water sample parameters were analyzed by the Chemical Laboratory personnel at the PPL System Facilities Center, Hazleton, Pennsylvania. This laboratory has state accreditation with the Pennsylvania Department of Environmental Protection (PADEP; Commonwealth of Pennsylvania 2010), identified as Lab #40-00568 (www.dep.state.pa.us). Water temperature and dissolved oxygen were measured by Ecology III personnel and river level was recorded with the SSES data (Table 2). PPL Susquehanna, LLC personnel provided data for Susquehanna River water withdrawal.

RESULTS AND DISCUSSION

River Flow, River Water Withdrawal, and River Temperature

In 2010, daily mean Susquehanna River flow ranged from 996 to 128,000 cubic feet per second (cfs; Table 3, Fig. 2). The monthly mean Susquehanna River flow was above the 49-year average for January, March, October, November, and December, and below

average for the remaining months (Fig. 3). For Luzerne County, the PADEP issued a drought watch on 6 August; this was changed to a drought warning on 16 September and conditions returned to normal on 11 November (www.depweb.state.pa.us keyword: Drought, accessed 3 February 2011). The annual precipitation at Avoca, PA (about 30 miles upriver from the Susquehanna SES) was 32.30 inches (5.26 inches below normal; www.erh.noaa.gov/bgm/climate/avp.shtml, accessed 13 January 2011). Cumulatively, an estimated 445 billion cubic feet of water flowed through this section of the Susquehanna River during 2010 (Fig. 4).

Susquehanna SES river water withdrawal of river flow ranged from <0.1% on 14 and 15 March to 8.28% on 28 September (Fig. 5). Daily river water withdrawal of the plant was ≤2% of river flow for more than two-thirds of 2010. River water withdrawal exceeded 4% of river flow on 49 days last year.

Daily mean river temperature ranged from 0.4 C on 1, 2, and 10 February to 28.9 C on 8 July (Table 4, Fig. 6). The hourly minimum river temperature of 0.3 C occurred at 0100 and 0200 h on 15 January. The hourly maximum river temperature of 30.6 C occurred at 1600 h on 7 July and 1700 h on 8 July. March and April tied (5.9 C in 2000 and 12.7 C in 2008, respectively) the warmest monthly mean river temperatures on record since 1974, for those months. July had the second warmest temperature in 37 years (exceeded by 0.3 C in 2005) for that month. River temperature was above average every month except January, October and December (Fig. 7). However, these temperature comparisons did not take into account variations in river flow among the months.

River Water Quality at the Susquehanna SES

Control and indicator data were compared to PADEP specific water quality criteria (Commonwealth of Pennsylvania 2009; Table 5). The parameters with published specific water quality criteria for the critical use of the Susquehanna River in the vicinity of the Susquehanna SES include alkalinity, ammonia nitrogen, dissolved oxygen, total iron, pH, and temperature. In 2010, Susquehanna River water met the published criteria for all collected samples at the control and indicator sampling sites (Table 6).

There have been significant decreases over time in certain indicators of abandoned mine discharge such as total iron and sulfate concentrations (Table 7, Fig. 8), and Ecology III, Inc. has long reported the biotic recovery in the river associated with these improvements.

Control and Indicator Site Comparisons

Control and indicator water quality data were similar on most of the sampling dates during 2010 (Table 6). Since most of the water taken from the river for plant operation is evaporated in the cooling process, the remaining cooling water returned to the river subsequently contains concentrated mineral solids. Mineral solids concentrations in the blowdown sample were 3.2 to 5.5 times greater than those of the river control (Table 6). However, the dilutive effect of high river flow tends to equalize values at the control and indicator sites. This is evident when TMS values of the blowdown are compared to the control and indicator TMS results (Tables 8 and 9). It has been previously demonstrated that TMS concentrations at SSES are the best predictor of TMS concentrations at Bell Bend at most river flows. In addition, if operation of the Susquehanna SES is to influence

the water quality at the indicator site, then the probability of that occurring should be greatest at low river flows (Ecology III, Inc. 2008).

Conclusion

Susquehanna River flow exceeded the 49-year average during five months in 2010 and was below average for the remaining months. The maximum river water withdrawal of river flow by Susquehanna SES was 8.28% on 28 September. On most days during 2010, however, river water withdrawal was ≤2% of river flow. Exceptionally warm river temperatures were recorded for March, April and July.

Water quality data demonstrated that river samples met the published specific water quality criteria for six common parameters. Overall, water quality of this section of the Susquehanna River continues to improve.

Our data analyses demonstrate that effects of the operation of Susquehanna SES on water quality of the Susquehanna River will likely occur at the lowest range of river flows. This is reasonable because the dilutive power of the river against plant discharge would then be minimized.

FISHES

PROCEDURES

Electrofishing

Electrofishing samples were collected once each month in May, June, July, August and October in 2010. Sampling was done at four sites, and each site was approximately 1,100-yards long and parallel to the river shoreline. These sites have been consistently sampled by boat electrofishing since 1976. Two sites were located upriver from the Susquehanna SES river intake structure along each bank of the river, and two sites were downriver from the intake (referred to as SSES and Bell Bend locations, respectively; Table 10, Fig. 1).

The 18-foot electrofishing boat was outfitted with a 5-KW generator (direct current). Electrical output was controlled by a variable-voltage pulsator, with a target of 5-6 amps delivered to the water.

During sampling, the boat was driven downstream parallel to the shoreline, usually within 30 feet of the riverbank. For both safety purposes and sampling efficiency, electrofishing was done at river levels less than 493.1 feet above mean sea level (msl; equivalent to 10.1 feet) as measured at the Environmental Laboratory. Sampling was done in the evening and began about one hour after sunset. Two observers stood in the bow of the boat and identified and counted fish during each sample. Data were recorded using a cassette tape recorder.

Seining

Shoreline fishes were collected by seine during June and August. Sampling was done when river levels were less than 490.2 feet above msl (equivalent to 7.2 feet at the Environmental Lab). Similar to the electrofishing sampling sites, two shoreline seine sites were above the Susquehanna SES river intake structure and two were below (Table 10, Fig. 1). High water prevented seining in October.

To seine, one end of the 25-foot bag seine (0.25-inch mesh) was kept stationary on the riverbank while the other end was extended about 20 feet into the river or as far as depth of the water allowed. The seine was then pulled upriver and onto shore. Two hauls were made in the same location at each site and the catches from both hauls were combined and considered one unit of effort. Captured fish were placed in 10% formalin in the field and returned to the laboratory. After at least two weeks in the formalin, the fish were rinsed with water, identified, and enumerated before final preservation in 40% isopropyl alcohol.

Statistical Analysis

A statistical analysis known as the Before-After:Control-Impact (BACI), was applied to the electrofishing (1976-2010) and seining data (1978-2010; Ecology III, Inc. 1990). Twenty species or categories of fish were analyzed from the electrofishing data, as were 12 species from the seining data. These species or groups were chosen based on their abundance during the years before Susquehanna SES operation.

Two different electrofishing data sets were analyzed. The first set included all months sampled by electrofishing through the years, and is referred to as the All Data set.

The second set, named the Summer Data set, included only the months from June through October to reflect the reduced monitoring effort in place since1986. The seining data set analyzed by the BACI represents all of the months sampled by this method through the years.

RESULTS AND DISCUSSION

Electrofishing

Electrofishing at the SSES and Bell Bend locations in 2010 resulted in the observation of 1,594 fish of 19 species (Tables 11 through 13). The total numbers of fish collected above and below the SSES intake and discharge for the year were generally similar, with 815 fish at the upriver sites and 779 fish at the downriver sites. Differences in monthly totals between upriver and downriver sites ranged from as few as 19 fish in May to as many as 147 fish in August; in most months more fish were observed at the upriver sites than at the downriver sites. Comparatively, the range of monthly sample sizes (maxima minus minima) between the east and west banks was 92 fish at SSES and 158 at Bell Bend. At both the upriver and downriver sites, more fish were observed in most months along the eastern shore of the river. Maximum monthly sample sizes occurred during October at SSES (275) and August at Bell Bend (308).

Walleye was the most abundant species observed at SSES and Bell Bend in 2010 (31% and 39% of the totals, respectively). Walleye and smallmouth bass together represented 49% of the fish observed at SSES and 60% of those at Bell Bend. Walleye was also the most abundant species during July, August, and October at SSES and during August and October at Bell Bend. Other species leading the list at SSES were smallmouth

bass during May and northern hog sucker in June. At Bell Bend, smallmouth bass were most abundant in May, followed by yellow perch in June and rock bass in July. Overall, 5-7% of fish observed were placed in the unidentified fish category at both sites during 2010.

Fifteen species were observed at SSES, as were 18 at Bell Bend. Species richness in monthly samples ranged from 7 to 13 species at SSES and 10 to 14 species at Bell Bend. Sucker and sunfish species dominated richness in all months during 2010.

Seining

Seining at the SSES and Bell Bend locations in 2010 resulted in the capture of 575 fish of 15 species (Tables 11 and 14). Spotfin shiner was the most abundant species captured at SSES (26%), as was spottail shiner at Bell Bend (45%). Spotfin shiner, bluntnose minnow and pumpkinseed comprised 63% of the fishes collected at SSES, while spotfin shiner and spottail shiner comprised 88% of the fish collected at Bell Bend.

Similar to previous years, the number of fishes captured at SSES was a fraction (44%) of those collected at Bell Bend. The disparity between the upriver and downriver locations may reflect changing habitat differences between the sites.

Thirteen species were collected at both SSES and Bell Bend. At both stations, species in the minnow and sunfish families predominated.

BACI Results: Electrofishing

Of the 20 species or categories of fish that were tested with the BACI analysis, eight species from the All Data set and eight species from the Summer Data set showed significant differences in the numbers of fishes above versus below the power plant

discharge (P≤0.05, Table 15). Species in the All Data set that indicated decreases in abundance below the power plant discharge included quillback, northern hog sucker, shorthead redhorse, muskellunge, rock bass, smallmouth bass, and unidentified fish. Brown bullhead was also significantly different; however, its numbers increased at Bell Bend compared to the upriver sites. The Summer Data set demonstrated decline or increase in all of the same species.

BACI Results: Seining

The results of the 12 seined species tested by BACI analysis indicated marginally significant differences in the numbers of spotfin shiner (P=0.096), spottail shiner (P=0.087) and rock bass (P=0.083) above versus below the plant discharge. The point estimates for these species indicated that more spotfin and spottail shiners were collected at the downriver sites versus upriver, while fewer rock bass were collected at the downriver locations.

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Table 1

Descriptions of water quality sampling sites in the vicinity of the Susquehanna SES, 2010.

SITE	LOCATION
Susquehanna SES Environmental Laboratory	West bank of the Susquehanna River: 1,620 feet (ft) upriver from the Susquehanna SES intake structure, sensors for river depth and temperature are located on river bottom within 100 ft of the bank
SSES (control)	Susquehanna River: 750 ft upriver from the center of the Susquehanna SES intake structure, 130 ft from the west bank
Blowdown	Since November 1996: Susquehanna SES Cooling Tower Blowdown Discharge Line 2S7 automatic composite sampler (ACS) about 750 feet downstream from the cooling tower basin, 0.1 air miles NNE from the stand-by gas treatment vent at 44200/N34117 (PA Grid System) December 1990-October 1996: 6S7 ACS at the Susquehanna SES sewage treatment plant about 2,880 feet downstream from the cooling tower basin
Bell Bend (indicator)	Susquehanna River: 2,260 ft downriver from the Susquehanna SES discharge diffuser, 130 ft from the west bank

Table 2

Water quality parameters and methods of analyses utilized by the Susquehanna SES Environmental Laboratory, 2010.

PARAMETER	METHOD	REFERENCE [a]
River depth (ft)	Seven-day continuous recording from an Acco Bristol, Model No. G500-15 bubbler-type water level gauge.	ACCO (1971)
River level (ft above msl)	$Level = Depth + 482.96$	Soya (1991)
River flow (cfs)	Insert river level into the appropriate regression equation. At level <486.0 ft, $\log flow = -0.05251(level)^2 + 51.478501(level) - 12612.85672$ At level ≥486.0 ft, $flow = 319.96989(level)^2 - 309316.24395(level) + 74753300$	Soya (1991)
Temperature (°F)	Constant monitor of river temperature: Seven-day continuous recording from an Omega RD-MV106-3-2-1D temperature recorder.	Omega (2001)
(°C)	River and blowdown temperature of samples collected: Calibrated, mercury-filled thermometer. Method 2550 B. Convert Fahrenheit to Celsius for tabulation: $^{\circ}C = (^{\circ}F - 32) \div 1.8$ or $\frac{^{\circ}C}{^{\circ}F - 32} = \frac{5}{9}$	APHA (1995) [b] Internet site
Dissolved oxygen (mg/L)	Membrane electrode. Method 4500-O G.	APHA (1995)

[a] Listed in references cited.
[b] http://mathforum.org/library/drmath/view/58393.html. Accessed: 19 February 2009.

Table 3

Daily mean flow (cfs) of the Susquehanna River at the Susquehanna SES Environmental Laboratory, 2010.

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	13100	21300	6180	66700	14900	3960	3710	2140	3960	16200	14000	18700
2	12700	16700	6490	56800	13100	3960	3960	1940	3460	66700	12700	71400
3	13500	15300	6800	45400	11500	3710	3460	1750	3230	57700	11500	85500
4	12300	15300	6800	37300	10300	3460	3230	1750	2770	44600	10700	60300
5	8470	13500	6490	30000	9910	3710	3230	1750	2560	33200	11100	46200
6	7450	11900	6490	25700	9540	3460	3000	1570	2350	31300	12700	33200
7	8120	10300	6490	22300	8820	3960	2770	1210	2140	41600	15800	26900
8	8820	10700	6490	20200	8820	8120	2560	1210	1940	41600	16200	22900
9	8470	9540	8470	18700	9910	11500	2140	1210	1750	30600	14000	19700
10	7450	9180	13100	18700	10300	9910	2140	1210	1750	24600	12700	16200
11	6800	8820	19200	18700	10300	8470	2140	1570	1570	19700	11900	14400
12	5880	8120	30000	16700	11100	8820	2140	1570	1570	17700	11100	14000
13	6490	7780	51000	14900	11100	7780	2350	1570	1570	17200	10700	17700
14	6180	7780	78300	13500	16200	8820	2770	1940	1570	15300	9910	23500
15	5880	7450	98600	12300	15800	8470	2770	1570	1570	14000	9180	25700
16	6800	6800	77300	10700	15300	8470	2140	1750	1570	12700	8820	22300
17	7120	6800	64800	10300	14400	7780	2140	1750	1390	12300	10700	18700
18	8120	6800	53400	10300	12700	6490	2350	1750	1210	17700	24600	15800
19	13500	6490	42400	11500	11500	5880	2140	1750	1210	19200	29400	14400
20	19700	5880	35900	11900	11500	5880	1940	1570	1390	15300	24000	13500
21	17200	5880	31900	11100	11500	5590	1940	1390	1390	13100	19700	12700
22	14000	5880	30000	9910	9540	5020	1570	1940	1390	11100	17200	11100
23	11500	5880	31900	9180	8470	4740	1570	2770	1210	9540	15300	10300
24	10300	5880	45400	8120	7450	4480	1750	3710	1210	9180	14000	9540
25	15300	5880	56800	8120	6800	4210	2560	4740	996	9180	14000	8820
26	114000	6180	51800	9180	6490	3460	3230	13100	996	8820	15300	8470
27	128000	5880	47000	11900	5880	3460	3460	12300	996	9540	17200	7120
28	81400	5590	40200	19700	5300	3460	3960	8820	996	15300	19700	7450
29	56000		36600	22900	5020	3460	4210	7120	996	22300	19200	6180
30	38000		37300	18700	4740	3460	3230	5880	1940	20700	16200	6180
31	28100		51800		4210		2560	4740		16700		6490
MEAN	22600	9050	35000	20000	10100	5800	2680	3190	1760	22400	15000	21800

Table 4

Daily mean temperature (C) of the Susquehanna River at the Susquehanna SES Environmental Laboratory, 2010.

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.5	0.4	3.0	6.6	14.3	25.7	24.4	25.7	25.1	19.0	10.2	6.1
2	0.5	0.4	3.7	7.9	16.0	25.7	24.0	25.5	25.9	16.7	9.4	6.8
3	0.5	0.5	4.3	9.4	17.4	25.9	24.3	25.3	26.1	16.0	8.9	5.8
4	0.5	0.6	4.4	11.0	17.9	26.4	25.2	26.2	25.0	15.5	8.8	4.8
5	0.5	0.7	4.5	12.0	18.3	26.4	26.3	26.8	22.9	14.6	8.6	4.3
6	0.5	0.7	4.5	13.0	18.8	26.0	27.6	26.5	22.0	14.1	8.2	3.5
7	0.5	0.5	4.9	13.8	18.8	24.6	28.8	26.2	22.6	14.1	7.7	2.9
8	0.5	0.5	5.5	14.8	18.8	23.4	28.9	26.3	23.0	14.1	7.4	2.3
9	0.5	0.5	6.1	14.8	16.6	22.1	28.8	26.7	21.5	14.4	7.3	1.5
10	0.5	0.4	6.4	13.6	15.2	20.7	28.1	27.2	20.8	14.2	7.6	0.8
11	0.5	0.6	6.5	13.1	14.6	20.8	28.0	27.4	20.8	14.3	7.8	0.6
12	0.5	0.8	6.4	13.0	13.5	21.5	27.1	26.5	19.9	14.7	7.5	1.0
13	0.5	0.9	5.2	12.9	13.3	22.9	26.9	26.1	20.4	14.5	7.2	1.9
14	0.5	0.7	4.3	13.0	13.9	23.2	26.7	25.6	20.4	13.7	7.1	1.2
15	0.6	1.0	3.8	13.6	15.1	23.3	26.8	24.4	20.1	12.8	7.3	0.5
16	0.9	1.5	4.3	14.2	16.0	23.5	27.3	24.7	19.4	12.1	7.6	0.5
17	0.9	1.5	4.9	14.1	16.4	22.6	27.8	24.9	19.6	11.7	8.2	0.5
18	1.1	1.7	5.6	12.8	16.2	22.5	28.3	24.6	19.6	11.6	8.4	0.5
19	0.9	2.3	6.2	12.3	15.9	23.4	28.2	25.2	19.9	11.3	7.9	0.5
20	0.5	3.0	7.1	12.6	16.5	24.7	27.9	25.7	19.8	11.1	7.3	0.5
21	0.6	3.3	8.0	13.3	18.0	25.5	28.3	25.2	19.4	10.9	6.9	0.5
22	0.7	3.4	8.7	13.9	19.0	25.6	28.1	24.7	20.0	10.5	6.9	0.5
23	0.6	3.4	9.1	14.1	19.5	25.8	27.3	23.9	20.9	10.1	7.2	0.6
24	0.9	3.7	8.9	14.4	19.8	26.0	28.3	23.1	21.5	10.4	7.1	0.5
25	2.3	3.4	8.1	14.4	21.3	26.4	27.8	22.5	22.3	11.0	6.7	0.5
26	2.6	2.2	7.5	13.7	23.4	26.6	27.3	22.2	21.2	11.8	6.3	0.5
27	2.0	1.7	6.8	13.3	24.8	26.7	27.1	22.2	20.6	12.8	5.7	0.5
28	1.7	2.3	6.1	12.0	25.0	26.9	27.3	22.1	21.2	13.1	5.2	0.5
29	0.9		6.1	11.6	24.5	26.5	27.4	22.5	20.8	13.0	4.7	0.5
30	0.5		6.2	12.5	24.5	25.6	27.0	23.4	20.1	12.1	4.7	0.6
31	0.5		5.7		25.3		26.6	24.3		11.1		0.6
MEAN	0.8	1.5	5.9	12.7	18.3	24.6	27.2	25.0	21.4	13.1	7.4	1.7

Table 5

Pennsylvania Department of Environmental Protection specific water quality criteria for the Susquehanna River in the vicinity of the Susquehanna SES, 2010.

PARAMETER	UNIT	PERIOD	CRITERIA		AVERAGE
			Minimum	Maximum	
Alkalinity as CaCO3	mg/L		20		
Ammonia Nitrogen	mg/L			4.56	
Dissolved Oxygen	mg/L		4.0		
		Daily Average	5.0		
Iron Total	mg/L	30-Day			1.5
pH			6.0	9.0	
Temperature	C	January 1-31		4.4	
		February 1-29		4.4	
		March 1-31		7.8	
		April 1-15		11.1	
		April 16-30		14.4	
		May 1-15		17.8	
		May 16-31		22.2	
		June 1-15		26.7	
		June 16-30		28.9	
		July 1-31		30.6	
		August 1-15		30.6	
		August 16-31		30.6	
		September 1-15		28.9	
		September16-30		25.6	
		October 1-15		22.2	
		October 16-31		18.9	
		November 1-15		14.4	
		November 16-30		10.0	
		December 1-31		5.6	

Table 6

Water quality data collected quarterly from the Susquehanna River and the Susquehanna SES blowdown, 2010. River sites were SSES (control) and Bell Bend (indicator). Analyses were performed at the PPL Chemical Laboratory, Hazleton, PA. N.D. = Not Detected

PARAMETER	UNITS	SSES	BLOW DOWN	BELL BEND	SSES	BLOW DOWN	BELL BEND
Date		3/11/2010	3/11/2010	3/11/2010	5/20/2010	5/20/2010	5/20/2010
Time		724	755	717	741	650	737
River level	ft	491.2			489.5		
Temperature	C	5.70	19.53	5.76	15.2	21.3	15.2
Dissolved oxygen	mg/L	15.04	10.35	14.62	10.13	6.89	10.13
pH, lab		8.06	8.97	8.06	7.86	8.77	7.84
Conductivity, lab	µmho	308	1510	318	234	693	236
Total alkalinity	mg/L	61.1	306	60.6	59.5	180	59
Phenolphthalein alkalinity	mg/L	0	30.9	0	0	10.4	0
Total suspended solids	mg/L	11.7	36.7	9.14	7.3	22.6	7.2
Ammonia as N	mg/L	<0.20	<0.20	N.D.	N.D.	<0.20	N.D.
Silicon dioxide	mg/L	2.76	17.6	2.59	0.922	4.28	0.894
Bicarbonate as CaCO3	mg/L	61.1	244	60.6	59.5	160	59
Carbonate as CO3	mg/L	0	61.8	0	0	20.8	0
Chloride	mg/L	43.9	250	46.6	23.7	87.1	23.8
Fluoride	mg/L	0.073	0.263	<0.100	0.064	<0.300	0.072
Nitrate as NO3	mg/L	2.46	15.1	2.56	0.91	4.2	0.96
Nitrate ion as N	mg/L	0.555	3.41	0.579	0.205	0.95	0.218
Phosphorus as PO4	mg/L	0.172	5.291	0.107	0.196	3.221	0.113
Sulfate	mg/L	17.6	116	18.6	18.7	56.8	18.8
Aluminum, dissolved	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Aluminum, total	ug/L	260	665	198	<100	329	<100
Barium, total	ug/L	33.5	156	32.8	26.1	83.3	26.6
Calcium, dissolved	mg/L	26.6	138	26.8	22.9	69.2	23
Calcium, total	mg/L	26.9	142	27.2	22.8	69.9	22.9
Copper, dissolved	ug/L	N.D.	<20.0	N.D.	N.D.	N.D.	N.D.
Copper, total	ug/L	N.D.	<20.0	N.D.	N.D.	<20.0	N.D.
Iron, dissolved	mg/L	0.115	0.327	0.11	0.088	0.236	0.088
Iron, total	mg/L	0.799	2.97	0.664	0.442	1.48	0.41
Magnesium, dissolved	mg/L	5.42	29.2	5.39	4.98	14.4	5
Magnesium, total	mg/L	5.48	30	5.53	4.96	14.7	5
Manganese, dissolved	ug/L	52.6	66.1	51.3	29	18.4	31.2
Manganese, total	ug/L	70.9	234	66.5	69.4	208	69
Nickel, total	ug/L	N.D.	<10.0	N.D.	<10.0	<10.0	<10.0
Potassium, dissolved	mg/L	1.68	7.38	1.65	1.28	3.69	1.27
Potassium, total	mg/L	1.73	7.53	1.68	1.27	3.81	1.31
Silver, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sodium, dissolved	mg/L	23.7	132	23.2	14.1	48.9	14
Sodium, total	mg/L	22.9	134	23.3	14	49.2	14
Strontium, total	ug/L	86.9	505	88.1	80.6	247	81.2
Vanadium, total	ug/L	<10.0	<10.0	N.D.	N.D.	<10.0	N.D.
Zinc, dissolved	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	<20.0
Zinc, total	ug/L	N.D.	<20.0	N.D.	N.D.	<20.0	<20.0
Beryllium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cadmium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium, total	ug/L	N.D.	<10.0	N.D.	N.D.	<10.0	N.D.
Lead, total	ug/L	N.D.	<5.00	N.D.	N.D.	<5.00	N.D.
Thallium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Arsenic, total	ug/L	<2.00	2.21	<2.00	<2.00	<2.00	<2.00
Selenium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Antimony, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total mineral solids	mg/L	160.73	888.49	163.77	123.23	396.92	123.13
Calcium hardness (C)	mg/L	66.4	345	66.9	57.2	173	57.4
Total hardness (C)	mg/L	89.7	478	90.7	77.4	235	77.8

Table 6 (cont.)

PARAMETER	UNITS	SSES	BLOW DOWN	BELL BEND	SSES	BLOW DOWN	BELL BEND
Date		9/2/2010	9/2/2010	9/2/2010	11/10/2010	11/10/2010	11/10/2010
Time		710	756	714	704	736	708
River level	ft	487.2			489.9		
Temperature	C	24.7	25.8	24.8	6.01	15.55	6.01
Dissolved oxygen	mg/L	8.9	8.6	10.5	12.48	10.64	12.67
pH, lab		7.84	8.64	7.86	7.75	8.71	7.77
Conductivity, lab	µmho	276	852	278	214	640	212
Total alkalinity	mg/L	69	141	69.6	56.5	164	56
Phenolphthalein alkalinity	mg/L	0	8.9	0	0	8.9	0
Total suspended solids	mg/L	5.2	16.6	5.2	<4.00	18	<4.00
Ammonia as N	mg/L	N.D.	<0.20	N.D.	N.D.	<0.20	N.D.
Silicon dioxide	mg/L	4.6	15.3	4.6	3.36	11.5	3.42
Bicarbonate as CaCO3	mg/L	69	123	69.6	56.5	146	56
Carbonate as CO3	mg/L	0	17.8	0	0	17.8	0
Chloride	mg/L	27.7	101	28	20.2	68	20.1
Fluoride	mg/L	<0.050	0.24	0.059	0.082	0.216	0.113
Nitrate as NO3	mg/L	1.36	5.99	1.35	1.41	5.22	1.59
Nitrate ion as N	mg/L	0.306	1.35	0.305	0.318	1.18	0.36
Phosphorus as PO4	mg/L	0.163	2.988	0.175	0.04	3.491	0.009
Sulfate	mg/L	21.5	145	21.7	16.3	67.4	17.6
Aluminum, dissolved	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Aluminum, total	ug/L	<100	269	<100	<100	368	<100
Barium, total	ug/L	30.9	92.5	30.8	23.3	72.3	23.7
Calcium, dissolved	mg/L	27.2	87.3	27.6	21.4	68.6	21
Calcium, total	mg/L	27.7	88.3	27.7	21.3	70.1	21.5
Copper, dissolved	ug/L	N.D.	<20.0	N.D.	N.D.	N.D.	N.D.
Copper, total	ug/L	N.D.	<20.0	N.D.	N.D.	N.D.	N.D.
Iron, dissolved	mg/L	0.108	0.198	0.109	0.162	0.412	0.155
Iron, total	mg/L	0.479	1.45	0.449	0.41	1.65	0.396
Magnesium, dissolved	mg/L	5.61	17.3	5.65	4.26	13.4	4.2
Magnesium, total	mg/L	5.69	17.6	5.66	4.25	13.8	4.3
Manganese, dissolved	ug/L	26.2	15.3	23.2	38.6	15.9	36.5
Manganese, total	ug/L	99.8	273	93.8	47	149	45.6
Nickel, total	ug/L	N.D.	<10.0	N.D.	N.D.	<10.0	N.D.
Potassium, dissolved	mg/L	1.97	5.92	1.92	1.44	4.16	1.36
Potassium, total	mg/L	1.93	6.03	1.92	1.39	4.29	1.37
Silver, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sodium, dissolved	mg/L	17.4	59.6	17.6	11.9	40.7	11.7
Sodium, total	mg/L	17.7	60	17.7	11.9	41.4	11.9
Strontium, total	ug/L	104	327	104	70.8	230	71.1
Vanadium, total	ug/L	N.D.	<10.0	<10.0	<10.0	<10.0	N.D.
Zinc, dissolved	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zinc, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Beryllium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cadmium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium, total	ug/L	N.D.	<10.0	N.D.	N.D.	N.D.	N.D.
Lead, total	ug/L	N.D.	<5.00	N.D.	N.D.	N.D.	N.D.
Thallium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Arsenic, total	ug/L	<2.00	3.15	<2.00	N.D.	<2.00	N.D.
Selenium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Antimony, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total mineral solids	mg/L	149	522	150	114	377	115
Calcium hardness (C)	mg/L	67.9	218	68.9	53.4	171	52.4
Total hardness (C)	mg/L	92.6	293	92.5	70.7	232	71.4

Table 7

Total iron concentrations from the Susquehanna River at the SSES sampling site, 1975-2010.
Samples were collected monthly from 1975 through 1996 and quarterly from 1997 through 2010.
PA DEP specific water quality criteria for total iron is 1.5 mg/L for a 30-day average.
Analyses were performed by the PPL Chemical Laboratory, Hazleton, PA.

YEAR	NO. SAMPLES Collected	NO. SAMPLES <1.50 mg/L	% SAMPLES <1.50 mg/L	ANNUAL MEAN
1975	12	2	16.7	3.55
1976	12	3	25.0	3.08
1977	11	5	45.5	1.71
1978	12	5	41.7	1.48
1979	12	5	41.7	3.13
1980	12	5	41.7	1.74
1981	12	9	75.0	1.31
1982	12	7	58.3	2.37
1983	11	6	54.5	1.41
1984	12	4	33.3	1.71
1985	12	5	41.7	1.61
1986	12	7	58.3	1.82
1987	12	8	66.7	1.96
1988	12	7	58.3	1.28
1989	12	9	75.0	1.45
1990	12	10	83.3	1.41
1991	12	10	83.3	0.98
1992	12	12	100.0	0.92
1993	12	8	66.7	1.55
1994	11	8	72.7	1.46
1995	12	12	100.0	0.89
1996	12	9	75.0	1.42
1997	4	4	100.0	0.55
1998	4	4	100.0	0.65
1999	4	4	100.0	0.60
2000	4	4	100.0	0.70
2001	4	4	100.0	0.74
2002	4	4	100.0	0.62
2003	4	3	75.0	1.43
2004	4	3	75.0	0.94
2005	4	4	100.0	0.57
2006	4	4	100.0	0.62
2007	4	3	75.0	2.00
2008	4	3	75.0	0.98
2009	4	2	50.0	2.98
2010	4	4	100.0	0.53

Table 8

Comparison of total mineral solids (TMS) concentrations from the Susquehanna River and the Susquehanna SES blowdown, 2010. River sites were SSES (control) and Bell Bend (indicator).

DATE	SSES		BLOWDOWN		BELL BEND	DIFFERENCE
	Flow (cfs)	TMS (mg/L)	Flow (cfs)	TMS (mg/L)	TMS (mg/L)	BELL BEND - SSES TMS (mg/L)
11 Mar	19200	160.7	13.4	888.5	163.8	3.1
20 May	11500	123.2	13.7	396.9	123.1	-0.1
02 Sep	3460	149.0	31.8	522.0	150.0	1.0
10 Nov	12700	114.0	33.6	377.0	115.0	1.0

Table 9

Comparison of annual average total mineral solids (TMS) concentrations from the Susquehanna River and the Susquehanna SES blowdown, 1991-2010. River sites were SSES (control) and Bell Bend (indicator).

YEAR	SSES		BLOWDOWN		BELL BEND	DIFFERENCE
	Flow (cfs)	TMS (mg/L)	Flow (cfs)	TMS (mg/L)	TMS (mg/L)	BELL BEND - SSES TMS (mg/L)
1991	12600	197.3	14.6	711.8	203.7	6.4
1992	13400	155.3	7.5	600.3	156.4	1.1
1993	23700	202.8	13.1	636.2	204.4	1.6
1994	19200	174.9	13.9	660.9	175.3	0.4
1995	10200	196.7	12.9	643.9	198.8	2.1
1996	24000	151.8	19.5	438.4	152.6	0.8
1997	6490	239.0	16.9	787.7	248.6	9.6
1998	11200	242.2	19.2	649.3	247.9	5.7
1999	9120	204.1	11.2	585.1	212.0	7.9
2000	21200	160.4	12.6	449.5	163.5	3.1
2001	7190	180.2	20.8	572.5	183.9	3.7
2002	12200	136.2	17.7	523.4	142.5	6.3
2003	26900	131.3	18.7	459.0	132.5	1.2
2004	12200	134.1	18.3	446.6	136.3	2.2
2005	13500	157.1	16.2	584.0	165.4	8.3
2006	14400	137.6	17.9	522.8	138.0	0.4
2007	20800	145.7	20.4	455.1	147.9	2.2
2008	10700	164.1	23.2	505.0	165.1	1.0
2009	30900	99.9	22.4	393.8	100.2	0.3
2010	11700	136.7	23.1	546.1	138.0	1.3
MEAN	15600	167.4	17.0	558.6	170.7	3.3

Table 10

Descriptions of electrofishing (EL) and seining (SN) sites at SSES and Bell Bend on the Susquehanna River, 2010.

SITE	LOCATION
	SSES (Control)
EL-1	East bank, 426 feet upriver from gas-line crossing to 1,082 feet upriver from a point opposite the center of the Susquehanna SES intake structure
EL-2	West bank from gas-line crossing to a point 820 feet upriver from the center of the Susquehanna SES intake structure
SN-1	East bank, 1,837 feet upriver from a point opposite the center of the Susquehanna SES intake structure (33 feet upriver from the mouth of Little Wapwallopen Creek)
SN-2	West bank, 1,312 feet upriver from the center of the Susquehanna SES intake structure (328 feet downriver from the boat ramp at the Susquehanna SES Environmental Laboratory)
	BELL BEND (Indicator)
EL-3	East bank, 1,279 feet downriver from a point opposite the center of the Susquehanna SES intake structure to a point 1,640 feet upriver from the mouth of Wapwallopen Creek
EL-4	West bank, 1,246 feet downriver from the center of the Susquehanna SES intake structure (558 feet downriver from the discharge diffuser) to a point near the southeastern boundary of PPL's Wetlands Nature Area
SN-3	East bank, 8,528 feet (1.6 miles) downriver from a point opposite the center of the Susquehanna SES intake structure, at the launching ramp of the Berwick Boat Club
SN-4	West bank, 4,264 feet (0.8 miles) downriver from the center of the Susquehanna SES intake structure, near the southeastern boundary of PPL's Wetlands Nature Area

Table 11

Fish species that were observed while electrofishing or collected by seining at SSES and Bell Bend on the Susquehanna River, 2010. Names of fishes and order of listing conform to Nelson et al. (2004).

COMMON NAME	SCIENTIFIC NAME
Herrings	Clupeidae
Gizzard shad	*Dorosoma cepedianum*
Carps and Minnows	Cyprinidae
Spotfin shiner	*Cyprinella spiloptera*
Common carp	*Cyprinus carpio*
River chub	*Nocomis micropogon*
Comely shiner	*Notropis amoenus*
Spottail shiner	*Notropis hudsonius*
Bluntnose minnow	*Pimephales notatus*
Fallfish	*Semotilus corporalis*
Suckers	Catostomidae
Quillback	*Carpiodes cyprinus*
White sucker	*Catostomus commersonii*
Northern hog sucker	*Hypentelium nigricans*
Shorthead redhorse	*Moxostoma macrolepidotum*
North American Catfishes	Ictaluridae
Channel catfish	*Ictalurus punctatus*
Pikes	Esocidae
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
Topminnows	Fundulidae
Banded killifish	*Fundulus diaphanous*
Sunfishes	Centrarchidae
Rock bass	*Ambloplites rupestris*
Redbreast sunfish	*Lepomis auritus*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieu*
Perches	Percidae
Tessellated darter	*Etheostoma olmstedi*
Yellow perch	*Perca flavescens*
Walleye	*Sander vitreus*

Table 12

Number, mean, and percent total of fish observed while electrofishing at SSES on the Susquehanna River, 2010.

SPECIES	27 May				24 Jun				29 Jul				26 Aug				25 Oct				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
Gizzard shad	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.4	0.1	0.1
Common carp	1	1	1.0	2.3	0	0	0.0	0.0	1	2	1.5	1.7	4	1	2.5	3.1	3	1	2.0	1.5	1.4	1.7
Fallfish	1	4	2.5	5.7	0	11	5.5	9.6	0	2	1.0	1.1	4	0	2.0	2.5	0	0	0.0	0.0	2.2	2.7
Quillback	5	3	4.0	9.2	4	5	4.5	7.8	8	4	6.0	6.8	2	7	4.5	5.6	19	12	15.5	11.3	6.9	8.5
Northern hog sucker	4	2	3.0	6.9	47	3	25.0	43.5	9	8	8.5	9.6	7	2	4.5	5.6	13	8	10.5	7.6	10.3	12.6
Shorthead redhorse	1	0	0.5	1.1	0	0	0.0	0.0	2	2	2.0	2.3	3	1	2.0	2.5	0	0	0.0	0.0	0.9	1.1
Sucker spp.	0	0	0.0	0.0	1	0	0.5	0.9	0	0	0.0	0.0	0	0	0.0	0.0	0	2	1.0	0.7	0.3	0.4
Channel catfish	5	2	3.5	8.0	0	0	0.0	0.0	1	1	1.0	1.1	1	1	1.0	1.2	0	0	0.0	0.0	1.1	1.3
Muskellunge	1	1	1.0	2.3	1	0	0.5	0.9	0	0	0.0	0.0	2	0	1.0	1.2	0	0	0.0	0.0	0.5	0.6
Pike spp.	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.6	1	0	0.5	0.6	1	0	0.5	0.4	0.3	0.4
Rock bass	6	7	6.5	14.9	9	11	10.0	17.4	9	11	10.0	11.3	20	0	10.0	12.4	12	6	9.0	6.5	9.1	11.2
Green sunfish	0	0	0.0	0.0	2	1	1.5	2.6	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.3	0.4
Pumpkinseed	0	1	0.5	1.1	0	0	0.0	0.0	0	1	0.5	0.6	3	0	1.5	1.9	0	0	0.0	0.0	0.5	0.6
Bluegill	0	0	0.0	0.0	0	0	0.0	0.0	7	2	4.5	5.1	1	0	0.5	0.6	0	0	0.0	0.0	1.0	1.2
Smallmouth bass	26	5	15.5	35.6	5	4	4.5	7.8	12	10	11.0	12.4	22	15	18.5	23.0	42	9	25.5	18.5	15.0	18.4
Sunfish spp.	1	1	1.0	2.3	1	1	1.0	1.7	4	6	5.0	5.6	1	1	1.0	1.2	0	0	0.0	0.0	1.6	2.0
Yellow perch	0	1	0.5	1.1	1	1	1.0	1.7	2	1	1.5	1.7	3	0	1.5	1.9	0	0	0.0	0.0	0.9	1.1
Walleye	2	0	1.0	2.3	1	2	1.5	2.6	25	33	29.0	32.8	44	2	23.0	28.6	48	94	71.0	51.6	25.1	30.8
Fish (unidentified)	4	2	3.0	6.9	2	2	2.0	3.5	8	5	6.5	7.3	9	4	6.5	8.1	3	1	2.0	1.5	4.0	4.9
TOTAL	57	30	43.5		74	41	57.5		89	88	88.5		127	34	80.5		142	133	137.5		81.5	

Table 13

Number, mean, and percent total of fish observed while electrofishing at Bell Bend on the Susquehanna River, 2010.

SPECIES	27 May				24 Jun				29 Jul				26 Aug				25 Oct				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
Common carp	2	0	1.0	2.9	0	0	0.0	0.0	4	1	2.5	6.1	7	3	5.0	3.2	3	0	1.5	1.2	2.0	2.6
River chub	1	0	0.5	1.5	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Fallfish	2	1	1.5	4.4	1	0	0.5	1.5	0	1	0.5	1.2	1	2	1.5	1.0	1	0	0.5	0.4	0.9	1.2
Quillback	3	2	2.5	7.4	13	0	6.5	19.4	2	2	2.0	4.9	3	0	1.5	1.0	9	11	10.0	7.9	4.5	5.8
White sucker	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.4	0.1	0.1
Northern hog sucker	0	4	2.0	5.9	3	3	3.0	9.0	0	0	0.0	0.0	4	5	4.5	2.9	5	4	4.5	3.5	2.8	3.6
Shorthead redhorse	1	0	0.5	1.5	0	0	0.0	0.0	1	1	1.0	2.4	0	0	0.0	0.0	1	0	0.5	0.4	0.4	0.5
Sucker spp.	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.4	0.1	0.1
Channel catfish	4	2	3.0	8.8	3	1	2.0	6.0	1	0	0.5	1.2	1	0	0.5	0.3	0	2	1.0	0.8	1.4	1.8
Northern pike	0	0	0.0	0.0	1	0	0.5	1.5	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Muskellunge	0	1	0.5	1.5	0	0	0.0	0.0	0	1	0.5	1.2	2	0	1.0	0.6	0	0	0.0	0.0	0.4	0.5
Pike spp.	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	1	1	1.0	0.6	0	0	0.0	0.0	0.2	0.3
Rock bass	3	1	2.0	5.9	2	2	2.0	6.0	12	3	7.5	18.3	43	8	25.5	16.6	1	8	4.5	3.5	8.3	10.7
Redbreast sunfish	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	1.2	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Green sunfish	0	0	0.0	0.0	2	1	1.5	4.5	2	1	1.5	3.7	0	0	0.0	0.0	0	0	0.0	0.0	0.6	0.8
Pumpkinseed	0	0	0.0	0.0	0	0	0.0	0.0	2	1	1.5	3.7	0	1	0.5	0.3	0	0	0.0	0.0	0.4	0.5
Bluegill	1	0	0.5	1.5	0	0	0.0	0.0	1	1	1.0	2.4	0	0	0.0	0.0	0	0	0.0	0.0	0.3	0.4
Smallmouth bass	9	18	13.5	39.7	5	3	4.0	11.9	9	4	6.5	15.9	57	11	34.0	22.1	13	31	22.0	17.3	16.0	20.5
Sunfish spp.	1	0	0.5	1.5	1	0	0.5	1.5	5	4	4.5	11.0	1	1	1.0	0.6	0	0	0.0	0.0	1.3	1.7
Yellow perch	0	0	0.0	0.0	14	0	7.0	20.9	2	0	1.0	2.4	2	0	1.0	0.6	0	0	0.0	0.0	1.8	2.3
Walleye	4	1	2.5	7.4	2	2	2.0	6.0	5	4	4.5	11.0	99	33	66.0	42.9	41	116	78.5	61.8	30.7	39.4
Fish (unidentified)	6	1	3.5	10.3	5	3	4.0	11.9	9	2	5.5	13.4	15	7	11.0	7.1	1	5	3.0	2.4	5.4	6.9
TOTAL	37	31	34.0		52	15	33.5		56	26	41.0		236	72	154.0		76	178	127.0		77.9	

Table 14

Number, mean, and percent total of fish captured by seining at SSES and Bell Bend on the Susquehanna River, 2010.

SPECIES	28 Jun				24 Aug				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
SSES										
Spotfin shiner	1	9	5.0	22.2	31	5	18.0	27.5	11.5	26.1
Comely shiner	0	0	0.0	0.0	1	0	0.5	0.8	0.3	0.6
Spottail shiner	0	0	0.0	0.0	2	5	3.5	5.3	1.8	4.0
Bluntnose minnow	14	0	7.0	31.1	9	4	6.5	9.9	6.8	15.3
Fallfish	2	0	1.0	4.4	0	0	0.0	0.0	0.5	1.1
White sucker	4	0	2.0	8.9	1	0	0.5	0.8	1.3	2.8
Rock bass	1	1	1.0	4.4	8	0	4.0	6.1	2.5	5.7
Redbreast sunfish	0	1	0.5	2.2	0	0	0.0	0.0	0.3	0.6
Green sunfish	0	0	0.0	0.0	11	11	11.0	16.8	5.5	12.5
Pumpkinseed	2	0	1.0	4.4	10	26	18.0	27.5	9.5	21.6
Smallmouth bass	1	0	0.5	2.2	1	1	1.0	1.5	0.8	1.7
Tessellated darter	4	4	4.0	17.8	4	1	2.5	3.8	3.3	7.4
Walleye	0	1	0.5	2.2	0	0	0.0	0.0	0.3	0.6
TOTAL	29	16	22.5		78	53	65.5		44.0	
BELL BEND										
Spotfin shiner	2	1	1.5	15.8	158	13	85.5	45.0	43.5	43.6
Spottail shiner	0	2	1.0	10.5	173	4	88.5	46.6	44.8	44.9
Bluntnose minnow	6	0	3.0	31.6	6	6	6.0	3.2	4.5	4.5
Fallfish	0	0	0.0	0.0	0	1	0.5	0.3	0.3	0.3
White sucker	2	0	1.0	10.5	0	0	0.0	0.0	0.5	0.5
Northern hog sucker	0	0	0.0	0.0	0	2	1.0	0.5	0.5	0.5
Banded killifish	0	0	0.0	0.0	3	2	2.5	1.3	1.3	1.3
Rock bass	1	0	0.5	5.3	2	2	2.0	1.1	1.3	1.3
Redbreast sunfish	0	0	0.0	0.0	0	1	0.5	0.3	0.3	0.3
Green sunfish	0	0	0.0	0.0	2	0	1.0	0.5	0.5	0.5
Pumpkinseed	0	0	0.0	0.0	1	3	2.0	1.1	1.0	1.0
Smallmouth bass	0	1	0.5	5.3	0	0	0.0	0.0	0.3	0.3
Tessellated darter	3	1	2.0	21.1	1	0	0.5	0.3	1.3	1.3
TOTAL	14	5	9.5		346	34	190.0		99.8	

Table 15

P-values for fish species deemed significant by the BACI analysis, 1976-2010 ($\alpha = 0.05$). Species listed decreased in number at the downriver locations, except for brown bullheads which increased at the downriver sites. Columns depict the p-values associated with the two temporal categories of data analyzed; All Data represents all months sampled, Summer Data denotes samples collected from June through October.

SPECIES	ALL DATA	SUMMER DATA
Quillback	0.007	0.002
Northern hog sucker	<0.001	0.011
Shorthead redhorse	<0.001	<0.001
Brown bullhead	0.005	0.047
Muskellunge	<0.001	0.003
Rock bass	<0.001	0.005
Smallmouth bass	0.032	0.001
Unidentified fish	0.024	0.001

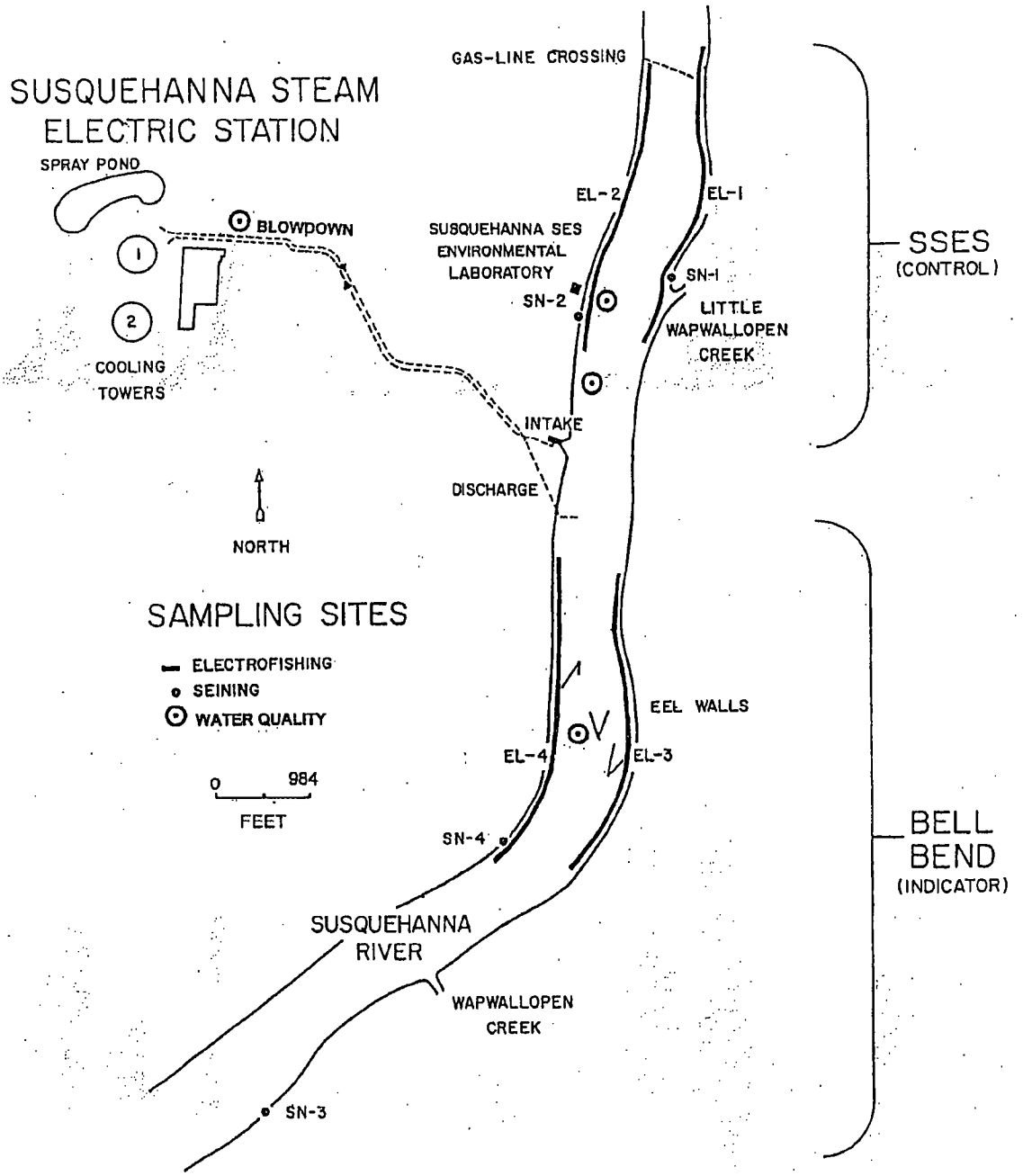

Fig. 1

Sampling sites for water quality, electrofishing (EL), and seining (SN) at SSES and Bell Bend on the Susquehanna River, 2010.

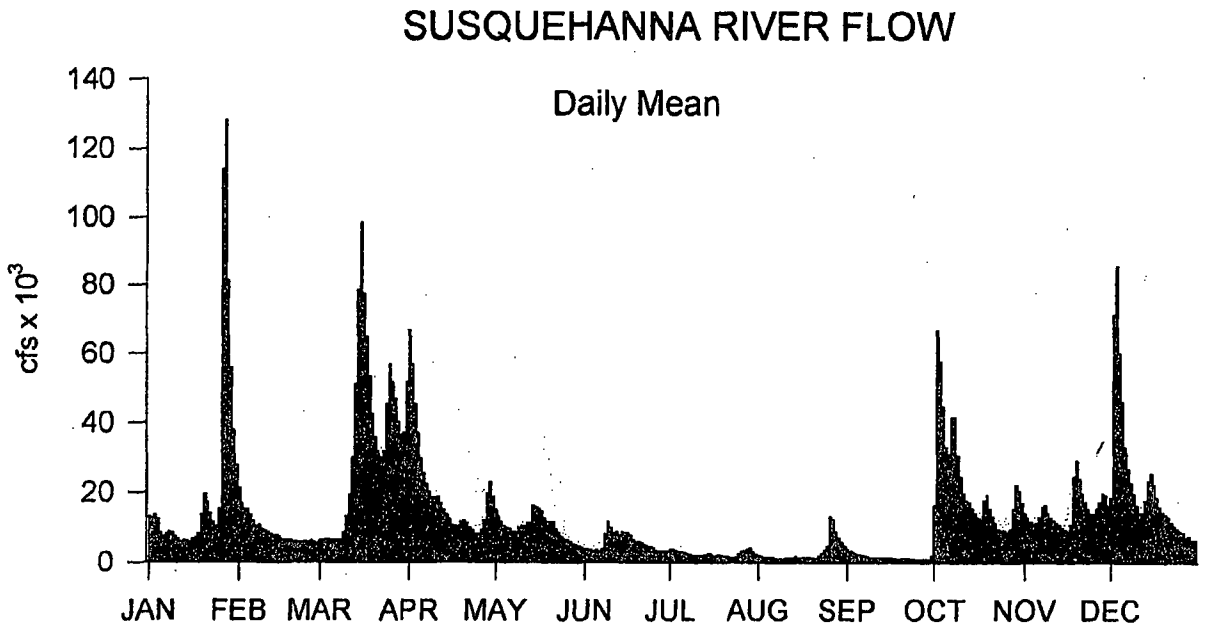

Fig. 2

The 2010 daily mean flow of the Susquehanna River at the Susquehanna SES Environmental Laboratory. The means were calculated from Environmental Laboratory data.

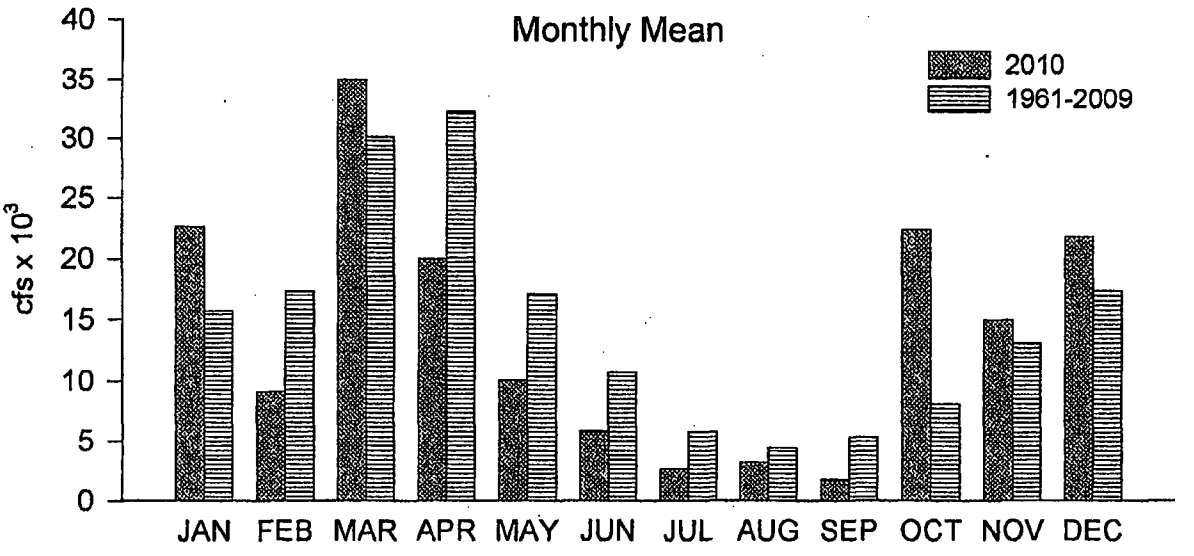

Fig. 3

The 2010 monthly mean flow of the Susquehanna River at the Susquehanna SES Environmental Laboratory compared to the 49-year (1961-2009) mean. The means were calculated from U.S. Geological Survey and Environmental Laboratory data.

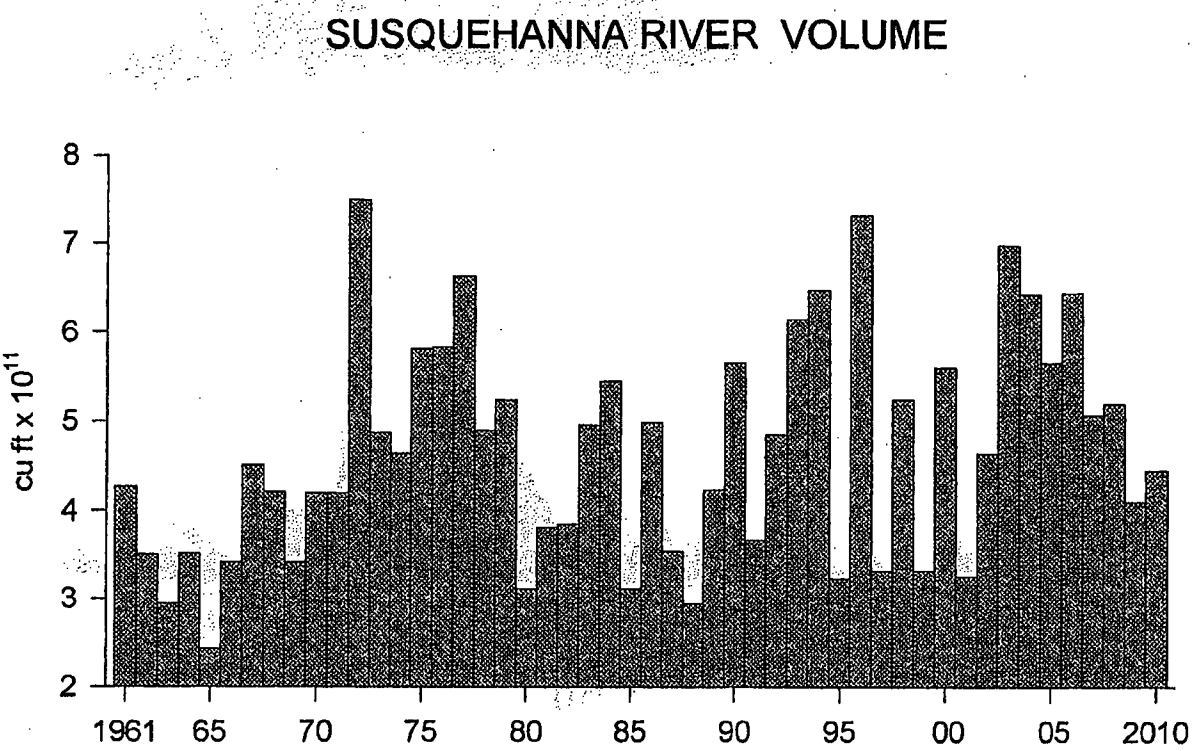

Fig. 4

Volume of Susquehanna River flow at the Susquehanna SES Environmental Laboratory, 1961-2010. The volumes were calculated from U.S. Geological Survey and Environmental Laboratory data.

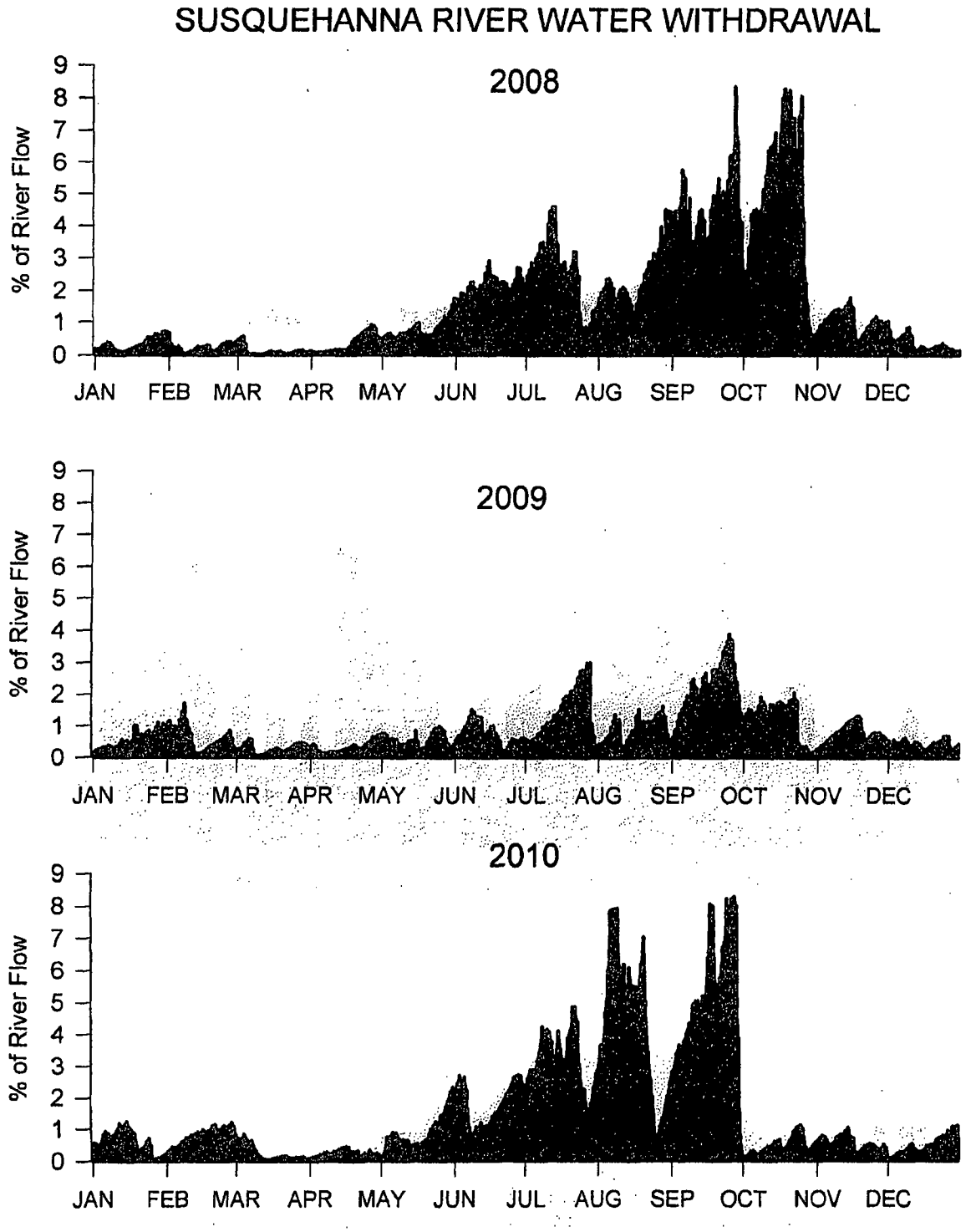

Fig. 5

Daily Susquehanna River water withdrawal by Susquehanna SES, 2008-2010.
Data provided by PPL Susquehanna, LLC personnel.

SUSQUEHANNA RIVER TEMPERATURE

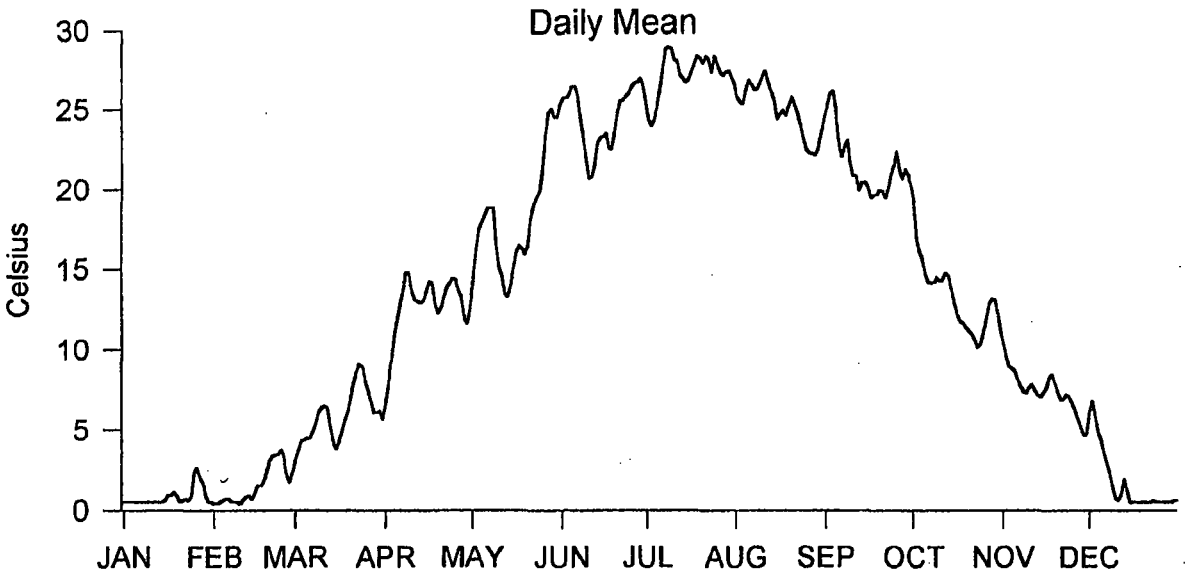

Fig. 6

The 2010 daily mean temperature of the Susquehanna River at the Susquehanna SES Environmental Laboratory.

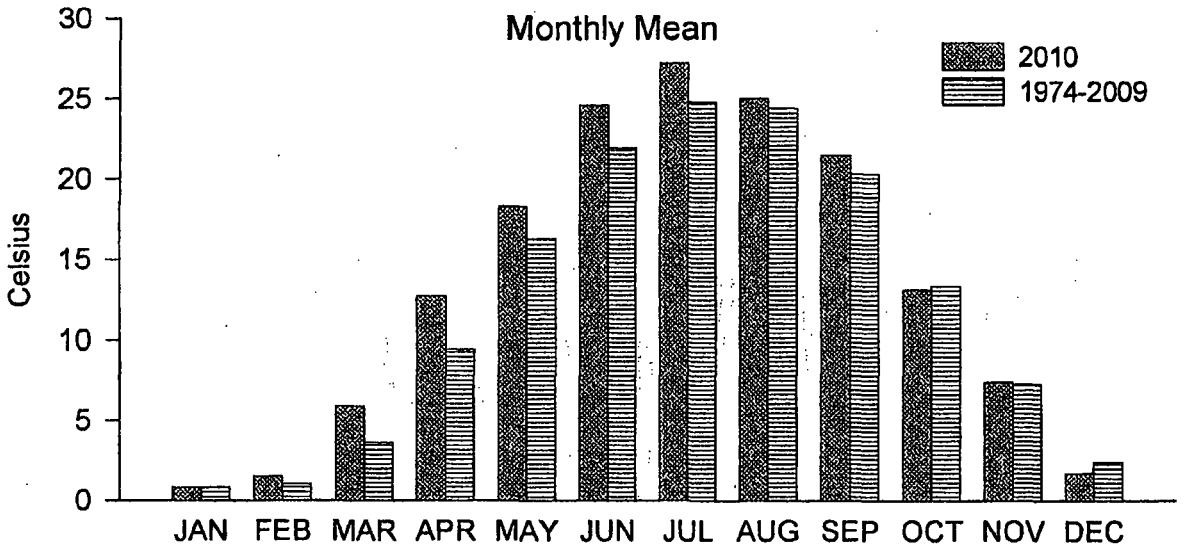

Fig. 7

The 2010 monthly mean temperature of the Susquehanna River at the Susquehanna SES Environmental Laboratory compared to the 36-year (1974-2009) mean.

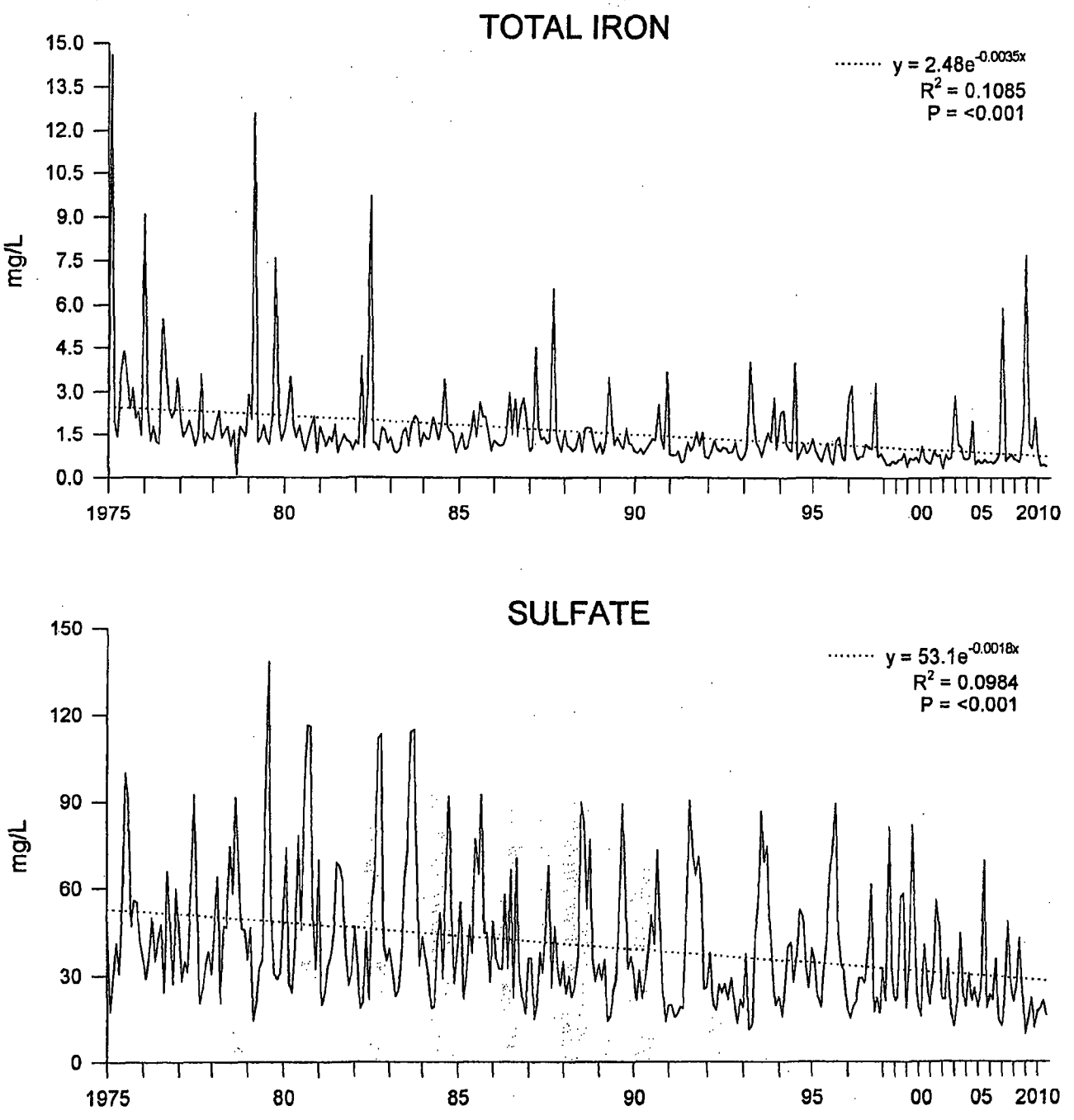

Fig. 8

Total iron and sulfate of the Susquehanna River at the SSES sampling site, 1975-2010. Samples were collected monthly 1975-1996 and quarterly 1997-2010. Analyses were performed by the PPL Chemical Laboratory, Hazleton, PA.